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(54) **METHODS FOR ALIGNING AN INGOT WITH MOUNTING BLOCK**

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B24B 5/50	(2006.01)

(52) **U.S. Cl.**

CPC ***B28D 5/0058*** (2013.01); ***B24B 5/50*** (2013.01); *Y10T 29/49998* (2015.01)

(58) **Field of Classification Search**

CPC B24B 5/50; H01L 21/304; B28D 5/0082
USPC 29/559, 407.04, 407.09, 407.05, 29/407.01; 269/55; 33/520
See application file for complete search history.

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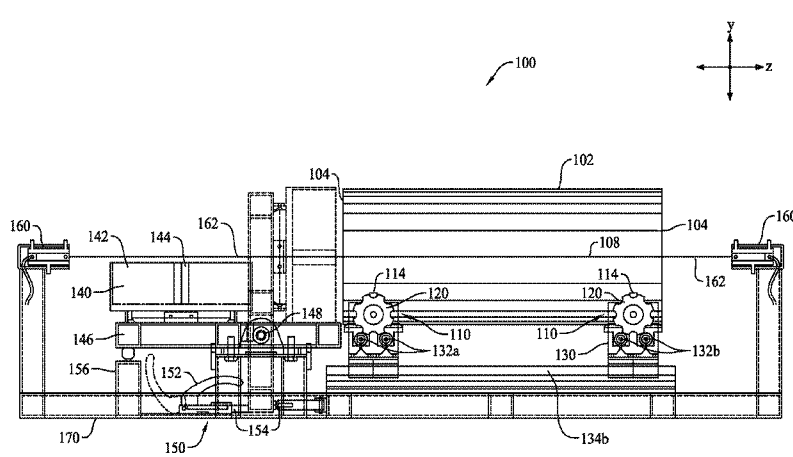
(57) **ABSTRACT**

A method of aligning an ingot of semiconductor or solar-grade material with a mounting block includes supporting the ingot using adjustable supports, aligning a predetermined centerline of the ingot with a reference line using a laser, and attaching the mounting block to the ingot such that the predetermined centerline remains aligned with the reference line.

15 Claims, 7 Drawing Sheets



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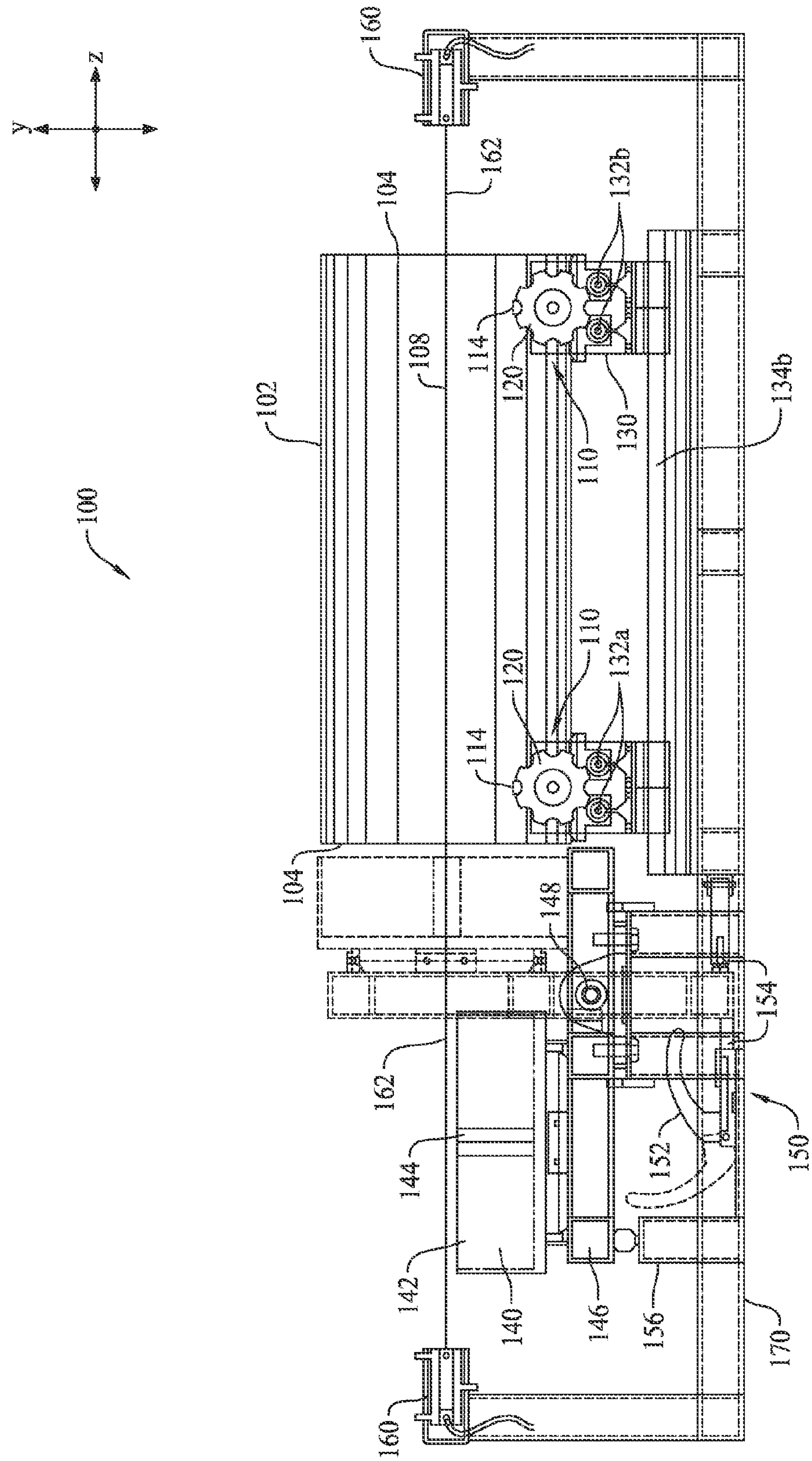
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160
162
104
108
102
114
120
110
130
132b
134b
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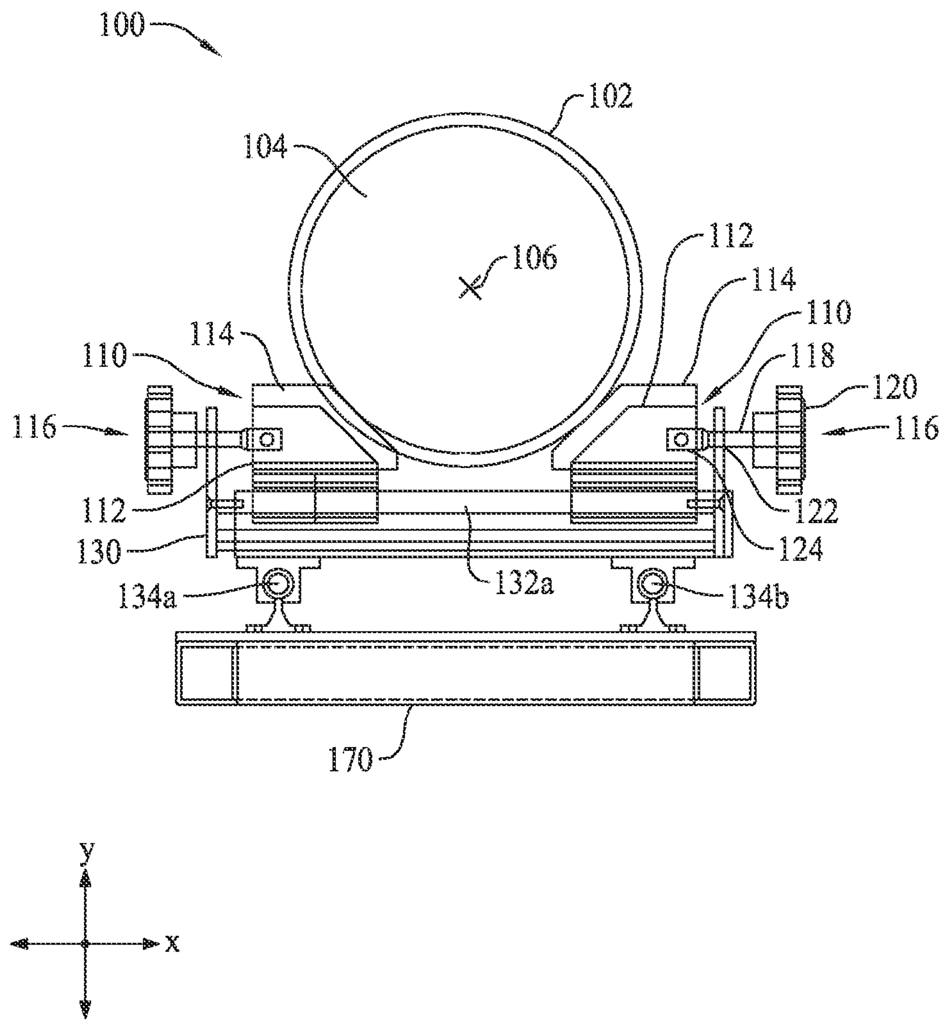
148
154
162
150
152
144
142
140
146
156
170
160

FIG. 1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134b
170
y
x

FIG. 2

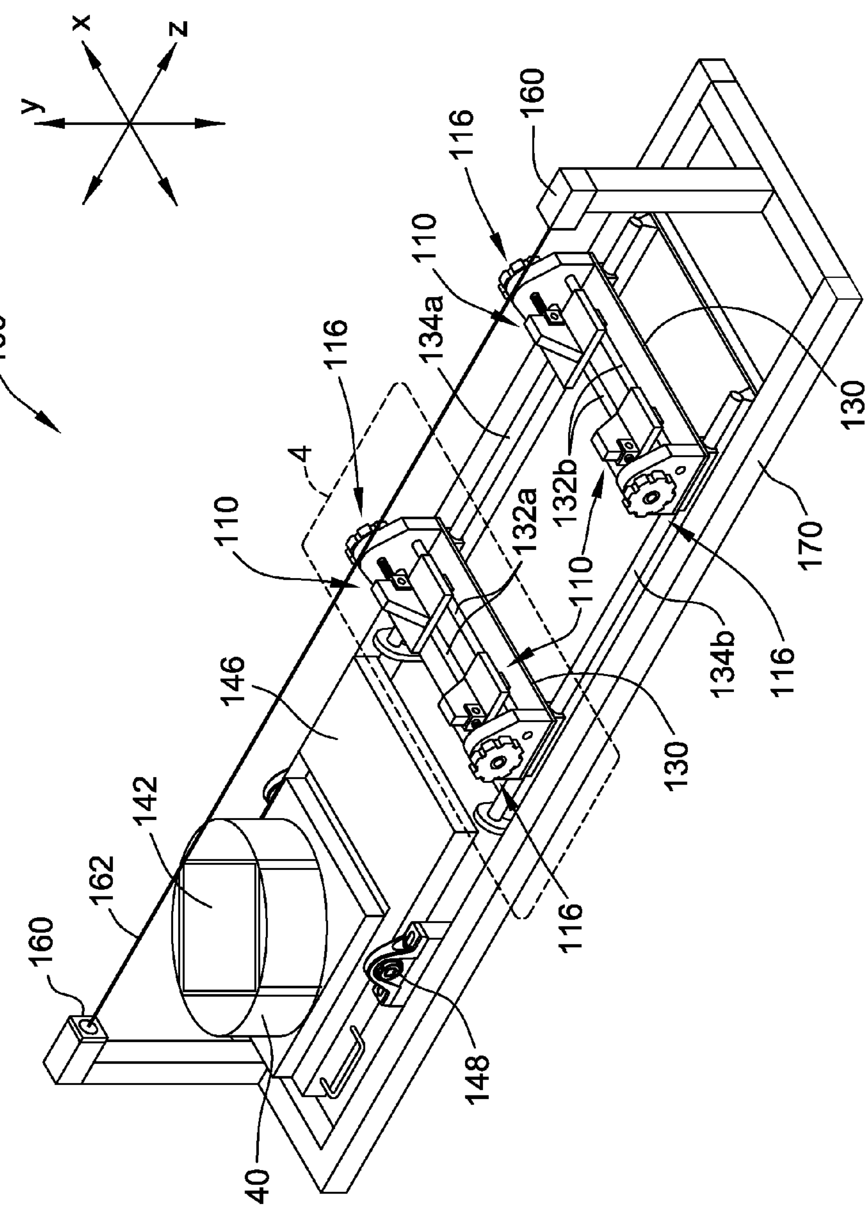
x
y
z
100
160
116
110
134a
116
4
110
132a
132b
110
130
170
116
134b
116
130
146
142
162
160
116
148
140

FIG. 3

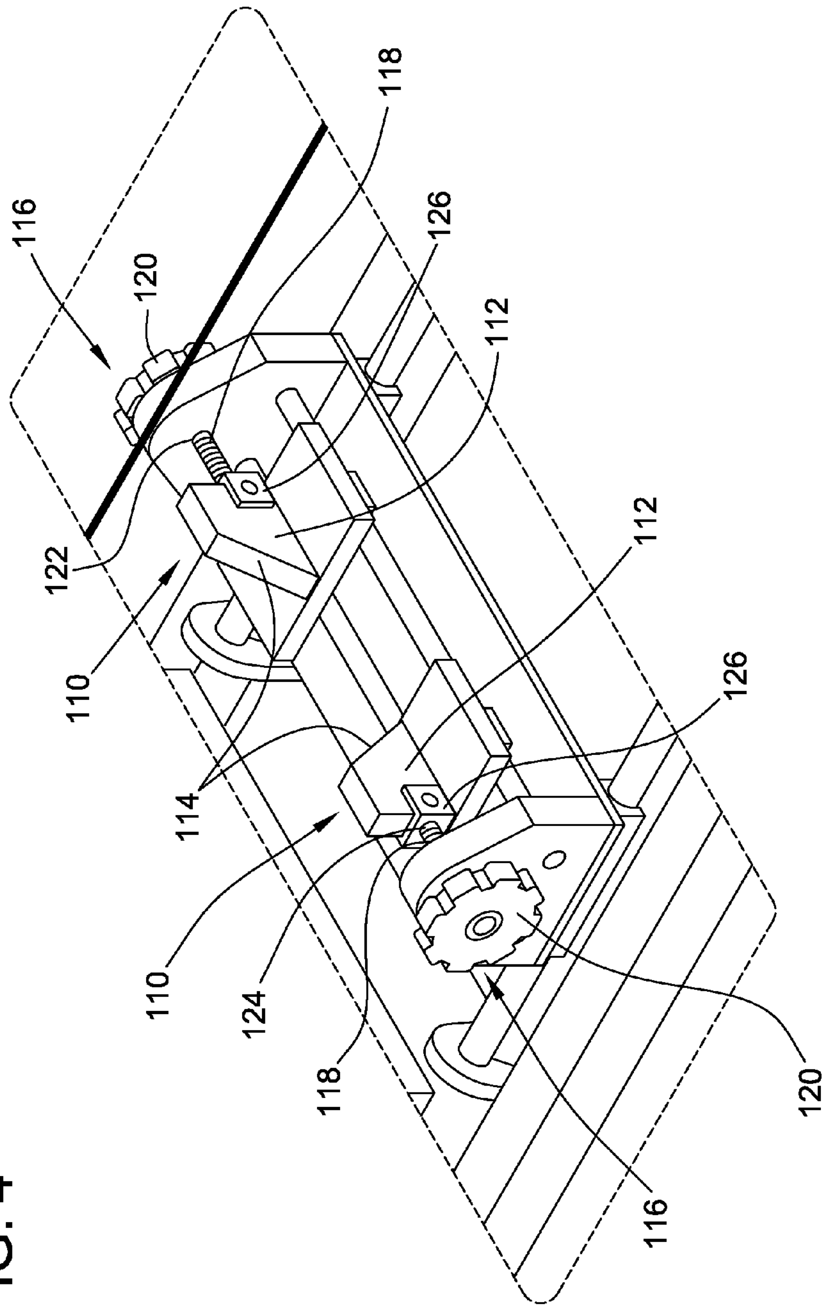

FIG. 4

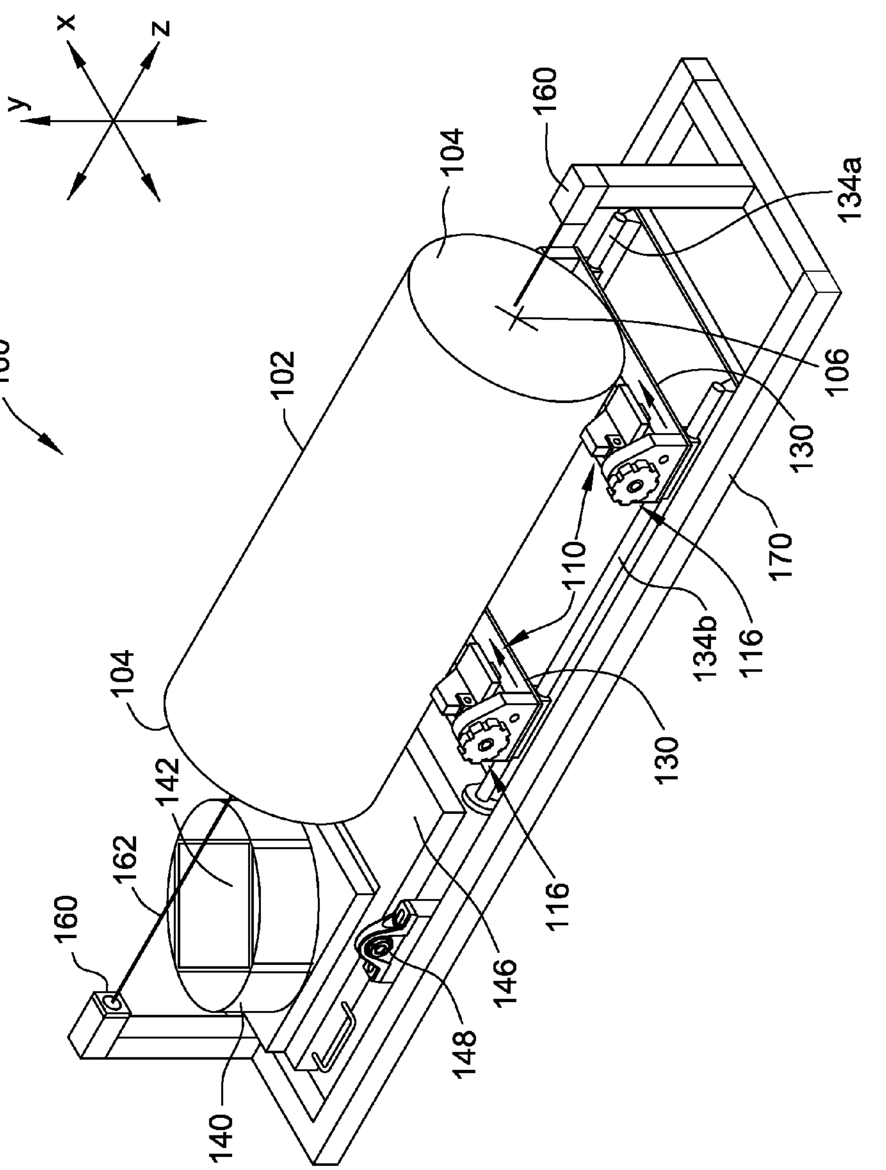
x
y
z
100
102
104
104
106
110
110
116
116
130
130
134a
134b
140
142
146
148
160
160
162
170

FIG. 5

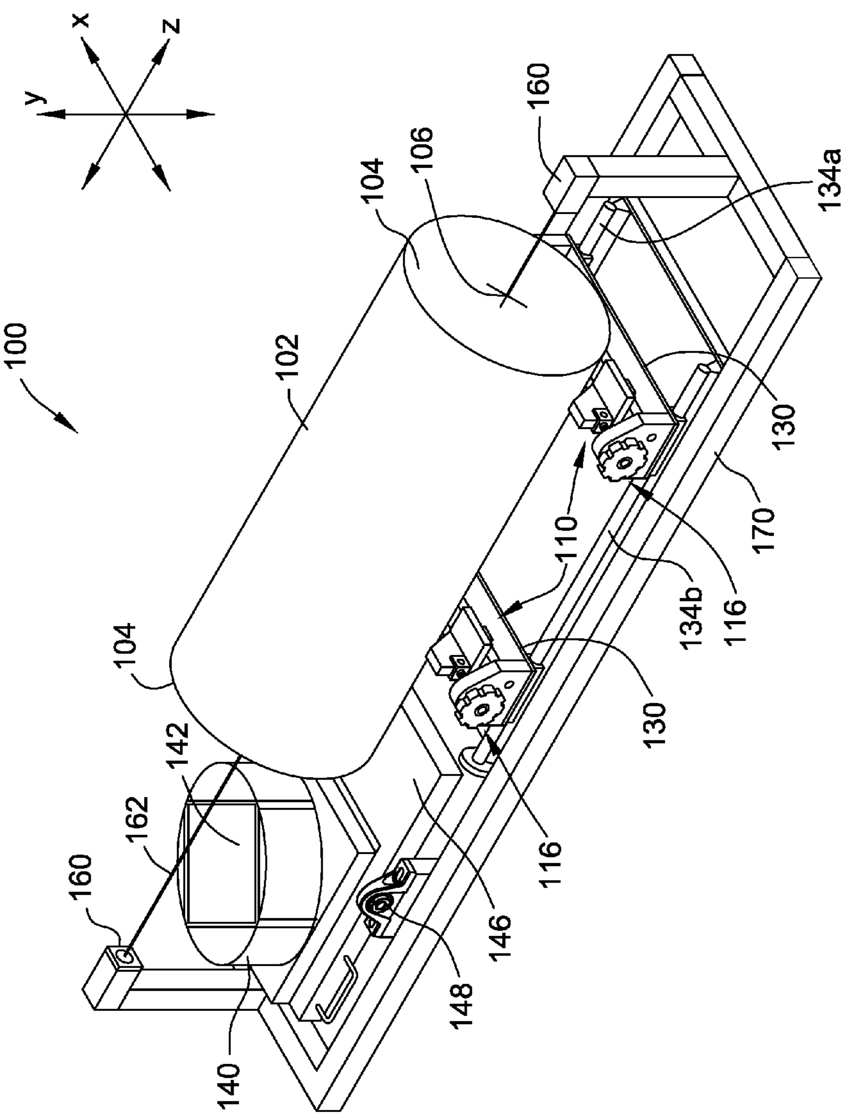
x
y
z
100
102
104
106
104
160
134a
130
170
110
134b
116
130
116
146
148
142
162
160
140

FIG. 6

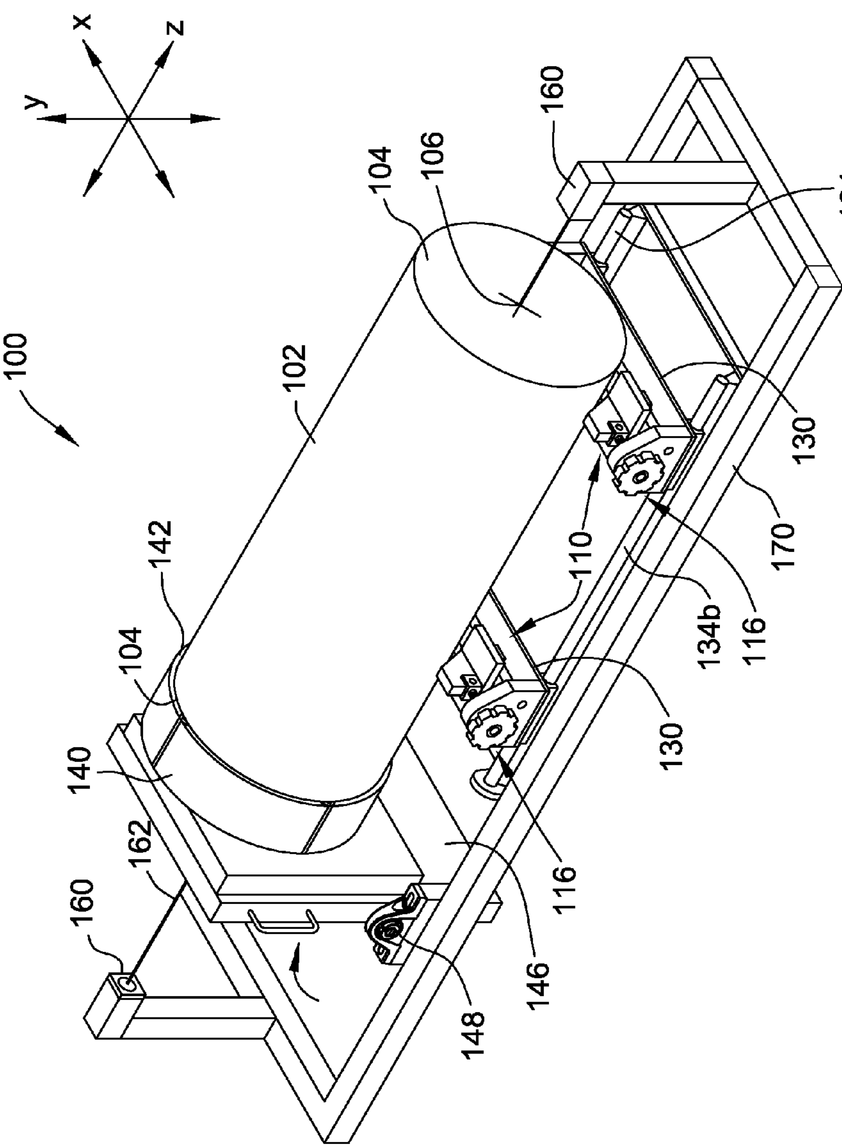
x
y
z
100
102
104
106
160
134a
130
170
116
134b
110
142
104
140
162
160
148
146
116
130

FIG. 7

METHODS FOR ALIGNING AN INGOT WITH MOUNTING BLOCK

FIELD

The field relates generally to systems and methods for processing ingots of semiconductor or solar-grade material into wafers and, more specifically, to methods for positioning such ingots for slicing.

BACKGROUND

Silicon and other semiconductor wafers used in semiconductor devices, as well as solar wafers used in solar devices, are generally prepared from an ingot. The typical ingot has a generally cylindrical shape, but is not a perfect cylinder. Once the ingot has been grown, the ingot is cut to have a desired cross-sectional shape (e.g., a pseudo-square). Typically, the ingot is mounted on a mounting block to carry out the cutting operation. In order to maximize the usable volume of the ingot and minimize the size of the ingot needed to cut the desired cross-sectional shape, a predetermined centerline of the ingot should be aligned with the center of a mounting block, such that when the ingot is placed in a cutting assembly, the axis along which the ingot is cut is substantially aligned with the predetermined centerline of the ingot. Once mounted, the axis defined by the center of mounting block should be substantially the same as the axis along which the ingot is cut during the cutting procedures. Thus, the predetermined centerline of the ingot should be aligned with the center of a mounting block to the extent possible.

Conventionally, the semiconductor ingot is aligned with the center of the mounting block by use of centering plates having a "V"-shaped notch, also known as "V"-block halves. "V"-block halves are disposed on opposite sides of the ingot, and are attached to a threaded screw such that the centering plates can be closed around the ingot by rotation of the threaded screw. By closing the "V"-block halves around the ingot, the "V"-shaped notches engage the outer surface of the ingot, thereby adjusting the position of the ingot with respect to a mounting block. Once the ingot is aligned, adhesive is applied to a vertically positioned mounting block, and the ingot is adhered to the mounting block. The "V"-block halves determine the centerline of the ingot to be aligned with the mounting block, and do not permit alignment of a predetermined centerline.

This conventional method has several drawbacks. Because of imperfections in the ingot's shape, use of the "V"-block halves may result in the ingot being off-center from its volume maximizing centerline, thus resulting in wasted material during the cutting procedure. This may be corrected or compensated for by shims. But attempts to correct by use of shims or the like are extremely time consuming, and often inaccurate because there is no reliable way for the operator to verify that the ingot is optimally positioned. Also, because the mounting block is disposed vertically in close proximity to the ingot, the operator has little room to apply adhesive to the mounting block, thus making the process difficult. Accordingly, a need exists for a better system or method for centering and aligning an ingot with a mounting block.

This Background section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the

present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

SUMMARY

In one aspect, a method of aligning an ingot of semiconductor or solar-grade material with a mounting block includes supporting the ingot using adjustable supports, aligning a predetermined centerline of the ingot with a reference line using a laser, and attaching the mounting block to the ingot such that the predetermined centerline remains aligned with the reference line.

In another aspect, a method of aligning an ingot of semiconductor or solar-grade material with a mounting block includes supporting the ingot using adjustable supports, providing a reference line for aligning a predetermined centerline of the ingot, aligning the predetermined centerline of the ingot with the reference line, rotating the mounting block from a generally horizontal position to a generally vertical position, and attaching the mounting block to the ingot such that the predetermined centerline remains aligned with the reference line. The predetermined centerline is based upon a predetermined cross-sectional shape to be cut from the ingot, and is indicated by a first mark and a second mark disposed on opposing faces of the ingot.

Various refinements exist of the features noted in relation to the above-mentioned aspects. Further features may also be incorporated in the above-mentioned aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to any of the illustrated embodiments may be incorporated into any of the above-described aspects, alone or in any combination.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of an alignment system of one embodiment;

FIG. **2** is a side view of the alignment system of FIG. **1** with the mounting block and lasers omitted;

FIG. **3** is a perspective view of the alignment system of FIG. **1** with the ingot omitted;

FIG. **4** is an enlarged view of the adjustable supports that support the ingot;

FIG. **5** is a perspective view of the alignment system of FIG. **3** with the ingot shown; and

FIGS. **6** and **7** are perspective views of the alignment system of FIG. **3** showing a method of aligning and mounting the ingot.

Like reference symbols used in the various drawings indicate like elements.

DETAILED DESCRIPTION

Referring now to FIGS. **1-4**, an alignment system of one embodiment for aligning an ingot **102** of semiconductor or solar-grade material with a mounting block is indicated generally at **100**. The ingot **102** is supported by a plurality of adjustable supports indicated generally at **110**.

As shown in FIGS. **1-4**, the ingot **102** is suitably supported in this embodiment by four adjustable supports **110**. Each adjustable support **110** is slidingly connected to a rail of a first pair of rails **132***a*, **132***b*. The rails **132***a*, **132***b* extend in a direction substantially perpendicular to the longitudinal axis of ingot **102**. Each rail **132***a* and **132***b* suitably includes two rails, as shown in FIGS. **1** and **3**, though a different number of rails may be used. As shown in FIG. **3**, each rail **132***a* and **132***b* is connected to two adjustable supports **110** disposed on opposite sides of ingot **102**. Rails **132***a* and **132***b* are mounted to support bracket **130**. Rails **132***a* and **132***b* are further connected to a second pair of rails **134***a*, **134***b* via support bracket **130**. Rails **134***a* and **134***b* are connected to frame **170**. Rails **134***a* and **134***b* are disposed on opposite sides of ingot **102** and extend in a direction substantially parallel to the longitudinal axis of ingot **102**. In this configuration, adjustable supports **110** move simultaneously in pairs along a second pair of rails **134***a*, **134***b*.

As shown in FIG. **4**, each adjustable support **110** includes a base **112**, and a support member **114** that engages the circumferential surface of ingot **102**. In the embodiment illustrated in FIGS. **1-4**, support members **114** are inclined planes disposed at an angle of about 45 degrees with respect to the horizontal. Inclined planes disposed at an angle other than 45 degrees are also suitable for use with this embodiment. Other structures are also suitable for use as support members **114**, such as discs, wheels, ball bearings, rollers and the like.

Alignment system **100** also includes a plurality of adjusters, indicated generally at **116**. Each adjustable support **110** is coupled to one of the adjusters **116**. Adjusters **116** are configured to move the adjustable supports **110** coupled thereto inwardly and outwardly with respect to the longitudinal axis of ingot **102**. Adjuster **116** can include, but is not limited to, rods, hydraulic cylinders, screws, bolts, and other devices suitable for moving adjustable supports **110** inwardly and outwardly with respect to the longitudinal axis of ingot **102**. In this embodiment, each adjuster **116** comprises an adjustment screw **118** coupled to a handle **120**.

Adjustment screw **118** is connected to support bracket **130** at a threaded opening **122** in support bracket **130** and is coupled to base **112** at receiving end **124**. Threaded opening **122** is threaded so as to engage the threads of adjustment screw **118** when handle **120** is rotated. Receiving end **124** includes a U-clamp or bracket **126** for coupling adjustment screw **118** to base **112**. Rotating handle **120** about the longitudinal axis of adjustment screw **118** causes the threads of adjustment screw **118** to engage the threads of threaded opening **122**, thereby causing adjustment screw **118** to move inwardly or outwardly with respect to the ingot **102**. In turn, adjustment screw **118** exerts a force on base **112** at receiving end **124**, thereby causing adjustable support **110** to move inwardly or outwardly with respect to the ingot **102**. Adjustment screws **118** may be finely threaded to allow for precise alignment of ingot **102**.

By moving adjustable supports **110** independently of or in conjunction with one another via adjusters **116**, ingot **102** can be moved in four degrees of freedom. Specifically, ingot **102** can be moved in the x and y directions of an x, y, z orthogonal coordinate system defined so that the face **142** of mounting block **140** is disposed in the x, y plane and the z-axis is perpendicular to mounting block face **142** when mounting block **140** is in a generally vertical position. Ingot **102** can also be rotated about the y-axis and the x-axis of the x, y, z orthogonal coordinate system by moving adjustable supports **110** independently of or in conjunction with one another via adjusters **116**. Ingot **102** can be moved in an additional degree of freedom—the z direction of the x, y, z orthogonal coordinate system—by sliding adjustable supports **110** in unison along rails **134***a* and **134***b*. The ease with which ingot **102** can be moved permits faster and more accurate alignment of ingot **102** with mounting block **140**. Further, because adjustable supports **110** can be moved independently of one another in the x-direction, the operator (not shown) of alignment system **100** can account for imperfections in the ingot's diameter or deviations along the longitudinal axis of the ingot without the use of shims or other time consuming corrections. Additionally, because adjustable supports **110** can be moved independently of one another in the x-direction, a predetermined ingot centerline **108** can be aligned with the center of the mounting block **140**.

The predetermined ingot centerline **108** is the line about which ingot **102** is cut once the ingot **102** is mounted on the mounting block **142** as described herein. The predetermined ingot centerline **108** is based upon a desired cross-sectional shape of the ingot **102** to be cut (e.g., a pseudo-square), and is determined based upon manual and/or computer aided measurements and calculations.

A mounting block **140** is positioned adjacent to one of the ingot faces **104**. Mounting block **140** is capable of being moved from a generally horizontal position to a generally vertical position (shown with dashed lines in FIG. **1**) such that mounting block face **142** is substantially parallel to one of the ingot faces **104** when in a generally vertical position. Having a mounting block movable from a generally horizontal position to a generally vertical position provides easy access to the face of the mounting block, which allows for precise application of adhesives to the face of the mounting block. In the embodiment shown in FIGS. **1** and **3**, mounting block **140** is connected to plate **146** via screws, bolts, pins or any other connection means suitable for connecting mounting block **140** to plate **146**. Plate **146** is pivotally connected to pivot **148**, which allows plate **146** to rotate between a generally horizontal position and a generally vertical position (shown with dashed lines in FIG. **1**). In turn, rotation of plate **146** causes mounting block **140** to move from a generally horizontal position to a generally vertical position. Plate **146** can be rotated by hand or mechanical means (not shown). A locking mechanism, indicated generally at **150** in FIG. **1**, is used to restrict movement of plate **146** when plate **146** is in a generally vertical position. In this embodiment, locking mechanism **150** comprises a lever **152** and locking members **154**. Lever **152** engages locking members **154** when moved from a first position (shown in FIG. **1**) to a second position (shown in ghost) such that locking members **154** restrict movement of plate **146** when plate **146** is in a generally vertical position. Optionally, a plate support member **156** is disposed adjacent to plate **146** to provide additional support to plate **146** when it is in a generally horizontal position (as shown in FIG. **1**).

One or more optical devices are positioned within alignment system **100** to aid the operator (not shown) in aligning predetermined ingot centerline **108** with mounting block **140**. In this embodiment, the one or more optical devices include two lasers **160** disposed on opposite ends of alignment system **100**. Lasers **160** are mounted to frame **170** facing each other such that the laser beam emitted by one laser coincides with the laser beam emitted from the other laser. The beams of lasers **160** thus define a single axis **162**. Lasers **160** are further positioned within alignment system **100** such that the single axis **162** defined by lasers **160** coincides with the axis defined by the center **144** of mounting block **140** when mounting block **140** is in a generally vertical position. When mounting block **140** is in a generally horizontal position, the beams emitted by lasers **160** are incident upon the respective ingot faces **104**.

In operation, a mark **106** is placed on each ingot face **104** for use in connection with the one or more optical devices. Any mark may be used for mark **106** (e.g., a dot, an "X", a circle, a ring, and the like).

In this embodiment, a mark **106** is placed on each ingot face **104** indicating the point to be aligned with the beam emitted by laser **160**. The line defined by the center of marks **106** coincides with the predetermined ingot centerline **108** to be aligned with mounting block center **144**. In the embodiment shown in FIGS. **2** and **4**, the mark **106** comprises an "X", although any mark may be used (e.g., intersecting lines, a dot, an "X", a circle, a ring, and the like) provided the mark indicates a point on ingot face **104** to be aligned with the beam emitted from laser **160**.

Referring now to FIGS. **5-7**, a method of using alignment system **100** of one embodiment will now be described with reference to the embodiment of alignment system **100** shown in FIGS. **1-4**. During use of the alignment system **100**, mounting block **140** is initially disposed in a generally horizontal position, as shown in FIG. **3**. Adjustable supports **110** are positioned to receive ingot **102**. As shown in FIG. **5**, ingot **102** is loaded onto adjustable supports **110**. Support members **114** support ingot **102** on at least four points along the circumferential surface of ingot **102**. If not already on, lasers **160** are turned on to emit beams incident upon each ingot face **104**. Prior to use of alignment system **100**, lasers **160** may need to be calibrated and/or adjusted to ensure that the beams coincide with one another and define a single axis **162**, and are perpendicular to mounting block face **142** when positioned in a generally vertical position. As shown in FIGS. **5** and **6**, ingot **102** is then aligned with the axis defined by the coincidental beams of lasers **160** by moving adjustable supports **110** via adjusters **116** until marks **106** are aligned with the laser beams. Once ingot **102** is aligned, mounting block **140** is attached to ingot **102** by moving mounting block into a generally vertical position.

As shown in FIG. **5**, the ingot centerline will generally not be initially aligned with the axis **162** defined by lasers **160**. Aligning ingot **102** is accomplished by moving one or more adjustable supports **110** via adjusters **116** until the marks **106** on ingot faces **104** are aligned with the beams emitted by lasers **160**. In the method shown in FIGS. **5-7**, the predetermined ingot centerline **108** is initially offset from the axis **162** defined by lasers **160**. To align marks **106**, the handles **120** of the adjustable supports on the near side of alignment system **100** are rotated, causing the adjustment screws **118** to engage the bases **112** of the adjustable supports **110** at receiving ends **124**. The adjustable supports **110** exert a force on the circumferential surface of ingot **102**, thereby causing ingot **102** to move in the direction of the x- and y-axes. Adjustable supports **110** are moved in the foregoing manner until the mark **106** on each ingot face **104** is aligned with the beam from laser **160** incident on the respective ingot face **104**, as shown in FIG. **6**. Because marks **106** define the predetermined ingot centerline **108**, aligning the marks **106** with the axis defined by coincidental beams of lasers **160** aligns the predetermined ingot centerline **108** with the axis defined coincidental beams of laser **160**.

As shown in FIGS. **6** and **7**, once the predetermined ingot centerline **108** is aligned, the mounting block **140** is attached to ingot **102**. The mounting block **140** is attached to ingot **102** such that the predetermined ingot centerline **108** remains aligned with the line defined by the coincidental beams of lasers **160**. In this method, adhesive is applied to the mounting block face **142** while mounting block **140** is in a generally horizontal position. Adhesive is used to secure the mounting block **140** to the ingot **102**, and to fill gaps between the mounting block **140** and ingot face **104** resulting from ingot face **104** not being perfectly parallel to mounting block face **142**. Mounting block **140** is then moved from a generally horizontal position into a generally vertical position, such that the mounting block face **142** is perpendicular to predetermined ingot centerline **108**. Ingot **102** is then moved along rails **134***a* and **134***b* via adjustable supports **110** such that ingot face **104** is brought into contact with mounting block face **142** and the adhesive.

In accordance with the present disclosure, ingots of semiconductor or solar-grade material can be aligned or positioned with the center of a mounting block faster and more accurately than prior art devices and methods. As further described herein, use of one or more optical devices and adjustable supports to align or position the ingot relative to the mounting block allows for faster and more accurate positioning and aligning of the ingot. Additionally, a predetermined centerline of an ingot of semiconductor or solar-grade material can be aligned with the center of a mounting block. As further described herein, use of independent adjustable supports allows for alignment of a predetermined ingot centerline with the center of a mounting block.

Various directional components of the foregoing systems and methods are described with reference to the ingot **102**. Because ingot **102** is not perfectly cylindrical, these directional components may not be purely perpendicular to or purely parallel to the longitudinal axis of ingot **102** or the ingot face **104**. Additionally, because ingot **102** is capable of being rotated about the x- and y-axes during use, these directional components may not be purely parallel to the longitudinal axis of ingot **102** or the ingot face **104**. Accordingly, the term "substantially" is used in connection with these various directional components to account for the non-perpendicular or non-parallel component of these directional components.

When introducing elements of the present invention or the embodiment(s) thereof, the articles "a", "an", "the" and "said" are intended to mean that there are one or more of the elements. The terms "comprising", "including" and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. The use of terms indicating a particular orientation (e.g., "top", "bottom", "side", etc.) is for convenience of description and does not require any particular orientation of the item described.

As various changes could be made in the above constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A method of aligning an ingot of semiconductor or solar-grade material with a mounting block, the method comprising:

supporting the ingot using adjustable supports;

aligning a predetermined centerline of the ingot with a reference line using a laser, wherein aligning the predetermined centerline includes moving the adjustable supports independently of one another in a first direction substantially perpendicular to the reference line such that the predetermined centerline is aligned with the reference line, and moving the adjustable supports in a second direction generally parallel to a longitudinal axis of the ingot;

rotating the mounting block about a pivot from a horizontal position to a vertical position; and

attaching the mounting block to the ingot such that the predetermined centerline remains aligned with the reference line.

2. A method as set forth in claim **1** wherein the adjustable supports include inclined planes.

3. A method as set forth in claim **1** wherein the step of aligning a predetermined centerline of the ingot includes using at least one laser to emit a laser beam to indicate the reference line.

4. A method as set forth in claim **3** wherein the predetermined centerline is indicated by two marks disposed on opposing faces of the ingot.

5. A method as set forth in claim **4** wherein the step of aligning a predetermined centerline of the ingot includes moving at least one of the adjustable supports in a direction substantially perpendicular to or substantially parallel to the longitudinal axis of the ingot such that the two marks become aligned with the laser beam emitted from the at least one laser.

6. A method as set forth in claim **1** wherein the step of attaching includes applying an adhesive to the mounting block while the mounting block is positioned horizontally.

7. A method as set forth in claim **1** wherein the step of attaching includes contacting one face of the ingot with the mounting block while the mounting block is positioned vertically.

8. A method as set forth in claim **1** wherein the predetermined centerline is based upon a predetermined cross-sectional shape to be cut from the ingot.

9. A method of aligning an ingot of semiconductor or solar-grade material with a mounting block, the method comprising:

supporting the ingot using adjustable supports;

providing a reference line for aligning a predetermined centerline of the ingot;

aligning the predetermined centerline of the ingot with the reference line, wherein the predetermined centerline is based upon a predetermined cross-sectional shape to be cut from the ingot and is indicated by a first mark and a second mark disposed on opposing faces of the ingot;

rotating the mounting block from a generally horizontal position to a generally vertical position; and

attaching the mounting block to the ingot such that the predetermined centerline remains aligned with the reference line.

10. A method as set forth in claim **9** wherein the step of aligning the predetermined centerline of the ingot includes moving the adjustable supports independently of one another in a direction substantially perpendicular to the reference line.

11. A method as set forth in claim **9** wherein the step of aligning the predetermined centerline of the ingot includes moving at least one of the adjustable supports in a direction substantially perpendicular to or substantially parallel to the reference line such that the predetermined centerline becomes aligned with the reference line.

12. A method as set forth in claim **9** wherein the step of providing a reference line includes emitting a laser beam from at least one laser.

13. A method as set forth in claim **12** wherein the step of aligning the predetermined centerline of the ingot includes moving at least one of the adjustable supports in a direction substantially perpendicular to or substantially parallel to the reference line such that the two marks become aligned with the laser beam.

14. A method as set forth in claim **12** wherein the step of emitting a laser beam from at least one laser further includes emitting a second laser beam from a second laser along the same axis as the first laser beam.

15. A method as set forth in claim **14** wherein the step of aligning the predetermined centerline of the ingot includes aligning the first mark with the first laser beam, and aligning the second mark with the second laser beam.

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